LUNG CANCER RATES CONVERGENCE IN YOUNG MEN AND WOMEN IN THE UNITED STATES: ANALYSIS BY BIRTH COHORT AND HISTOLOGIC TYPE

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Age-specific rates of lung cancer have been consistently higher for men than for women in the United States, due primarily to different patterns of cigarette smoking. Gender differences in cigarette smoking have diminished in recent birth cohorts, however, especially among whites. We used U.S. population-based incidence and mortality data and examined trends in age-specific rates of lung cancer by birth cohort according to gender, ethnic group, and histology to evaluate the generational changes in U.S. lung cancer risk for men *vs.* women. All tests of statistical significance are 2-sided (95% confidence interval [CI]). Lung cancer mortality rates have converged between men and women born after 1960, especially in whites. The male-to-female (M:F) mortality rate ratio for ages 35–39 years decreased from 3.0 (95% CI = 2.7–3.4) around the 1915 birth cohort to 1.1 (95% CI = 1.0–1.1) around the 1960 birth cohort among whites and from 4.0 (95% CI = 3.2–5.0) around the 1925 birth cohort to 1.5 (95% CI = 1.3–1.7) around the 1960 birth cohort among blacks. Similarly, incidence rates for white men and women converged rapidly for adenocarcinoma, small cell carcinoma, and large cell carcinoma, but less so for squamous cell carcinoma. These findings reflect the smoking patterns among white and black men and women: cigarette smoking prevalence at age 24 was essentially equal among white men and women born after 1960 but continued to be higher in black men than women. The convergence of lung cancer death rates among men and women born after 1960s supports the idea that males and females maybe equally susceptible to develop lung cancer from a given amount of cigarette smoking, rather than the hypothesis that women are more susceptible.
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Cigarette smoking accounts for about 78% and 90% of deaths due to lung cancer in U.S. women and men, respectively.[1] Cigarette smoking and subsequent lung cancer mortality patterns by birth cohorts have shown parallel trends in the U.S.[2] Smoking[3] and mortality[4] rates reached a maximum among men born in the 1920s and among women born in the 1930s. Men have historically had higher rates of lung cancer than females because of their higher smoking rates. Smoking prevalence for men and women has become similar in the younger generation,[5] however, especially among whites.

Many studies have reported that women are more susceptible to develop lung cancer than men for equal levels of tobacco exposure.[6–13] Recent findings from the United States[14] and European countries,[15–17] however, do not support a higher susceptibility of women to tobacco smoke. We evaluate the generational changes in U.S. lung cancer risk for men versus women by analyzing trends in population-based lung cancer mortality and incidence rates by birth cohort and ethnic group to see if the ratio has diminished or reversed.

MATERIAL AND METHODS

Mortality data from the National Center for Health Statistics are available since 1950 for whites and nonwhites and since 1970 for blacks. To provide long-term comparisons between genders, we used the 1950–69 nonwhite mortality rates as a surrogate for the death experience of blacks; blacks represented about 92% of the nonwhite population during this period.[18] Based on the number of deaths due to cancers of the lung, trachea, bronchus, and pleura (ICD Codes: 6,7, 8, and 9 [162–163], 10 [C33–34, C38.4]),[19–23] we calculated age-specific rates for white and black men and women by 5-year age groups (25–29, …, 85+) and 5-year calendar periods (1950–54, 1955–59, …, 1990–94, 1995–99) using population estimates from the Census Bureau. Because only a few deaths occurred in the 25–29 year age group in blacks, this category was excluded from analyses.

Incident cases of invasive carcinoma of the lung and bronchus were identified from the SEER program of the National Cancer Institute, nine population-based cancer registries, which encompassed approximately 10% of the U.S. population.[24] Each of the 9 registries became a part of the SEER program by 1975. Incidence rates by major histologic types of lung cancer were calculated for white and black men and women by 5-year age categories (35–39, 40-44, …, 50–54) and 5-year calendar periods (1975–79, 1980–84, 1985–89, 1990–94, 1995–99). Based on morphology codes of the WHO International Histological Classification of Tumors,[25] invasive carcinomas of the lung and bronchus were categorized into 4 major histologic types: squamous cell carcinoma (8051–8052, 8070–8076, 8120 and 8123), small cell carcinoma (8041–8045), large cell carcinoma (8011–8012 and 8020–8021), and adenocarcinoma. The latter category included specified and unspecified adenocarcinoma (8140–8141, 8143, 8290, 8310, 8320, 8323, 8470–8471, 8480–8481, 8490, 8550 and 8570–8572), papillary adenocarcinoma (8050 and 8260), and bronchioloalveolar carcinoma (8250–8251). Other specific and non-specific histologic types of carcinomas (8002, 8004, 8010, 8022, 8030–8034, 8190, 8200–8201, 8230, 8240–8247, 8430, 8940, 8972 and 8981) were placed into a miscellaneous category. Until 1977, large cell carcinoma was classified as an unspecified carcinoma; so data before 1980 were excluded for analyses of large cell carcinoma.

Ethnic group-, gender-, and age-specific mortality and incidence, by histologic category, rates were then plotted by birth cohort using semi-log ordinate scales[26] to facilitate comparison of rates visually. Graphical comparison of rates in young men and women were further facilitated by restricting presentation of data to age under 55 years. Birth cohort year for rates was derived by subtracting age at death/diagnosis (middle of 5-year age group)

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from calendar year of death/diagnosis (middle of 5-year calendar period). Ninety-five percent confidence intervals (CI) for age-specific lung cancer mortality and incidence male-to-female rate ratios were estimated by exp(ln(RR)1.96*SD), where SD (standard deviation) is the square root of the reciprocal of the sum of total events in the ethnic group-, gender- and age-specific category.

Ethnic group- and gender-specific current smoking prevalence data by 5-year birth cohort were available from published work of Burns *et al.*,[27] as estimated by pooling 16 calendar years of National Health Interview Survey data on smoking, spanning from 1965–90. Current smoking prevalence was calculated by the percentage of the population that has smoked at least 100 cigarettes and has initiated by a given age multiplied by the fraction of those ever-smokers that age who had not quit. We plotted the current smoking prevalence data for age 24 and 40 years by 5-year birth cohort intervals for white and black males and females to assess the gender differences in the initiation and cessation of smoking and relate these differences with the changes in lung cancer incidence and mortality patterns.

RESULTS

Figure 1 shows age- and gender-specific mortality rates of lung cancer by birth cohort for whites (*left panel*) and for blacks (*right panel*). Among whites, there was a prominent convergence of age-specific rates between men and women in the successively younger birth cohorts. This was quantified by the male-to-female

age-specific mortality rate ratios (Table I). The rate ratios increased in cohorts born before 1890, and peaked in cohorts born between 1890 and 1900, with a maximum of 9.3 (95% CI = 9.0–9.6) for age group 65–69 born around 1895. The ratios declined in the successively younger birth cohorts in all age groups, with a minimum of 1.1 (0.8–1.4) for age group 25–29 born around 1970.

The age-specific mortality patterns for blacks (Fig. 1, *right panel*) were generally similar to those for whites, but the extent of convergence of male and female curves were much less for blacks. The male-to-female lung cancer mortality rate ratios peaked in cohorts born between 1890 –1915, with a maximum of 8.2 (7.3– 9.2) for 65– 69 years old born around 1895 (Table I). Ratios have declined monotonically in successively younger generations, but less than for whites in every age group. It is interesting to note that for equivalent age and birth cohorts, M:F rate ratios were higher in whites than in blacks for the cohorts born before 1900, except for the very oldest age groups. For cohorts born after 1910, in contrast, the ratios were higher in blacks than in whites; none of the 95% CI ratio estimates for ages 45 years and over and born after 1915 overlapped between whites and blacks. It is also noteworthy the slight increase in lung cancer rates in women and the moderation in the rate of decrease in men for cohorts born after 1950 (Fig. 1), which have been related previously to an increase in teenage smoking from the mid-1960s to the late 1970s.[28]

Figure 2 depicts the age-specific incidence patterns for 4 major histologic types of lung cancer by birth cohort for whites (*upper*
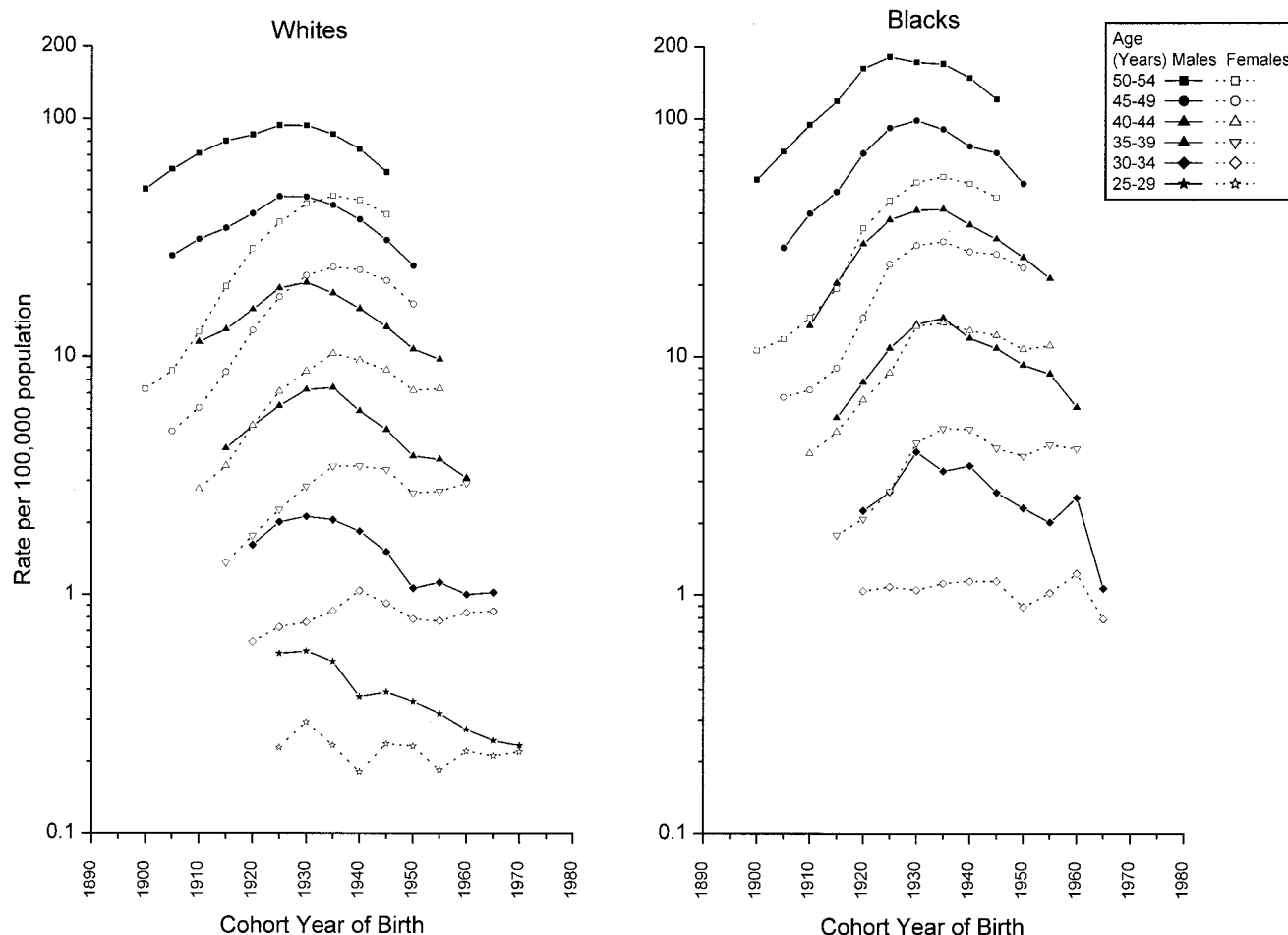

FIGURE 1 – Age-specific U.S. mortality patterns among white males and females by birth cohort, 1900–1970.

TABLE I – MALE TO FEMALE LUNG CANCER MORTALITY RATE RATIOS (95% CI)[1]

Cohort	Age					
	25–29	30–34	35–39	40–44	45–49	50–54
Whites						
1865						
1870						
1875						
1880						
1885						
1890						
1895						
1900						6.9 (6.5–7.3)
1905					5.5 (5.1–5.8)	7.0 (6.7–7.4)
1910				4.1 (3.8–4.5)	5.1 (4.8–5.4)	5.6 (5.4–5.8)
1915			3.0 (2.7–3.4)	3.7 (3.5–4.0)	4.0 (3.8–4.2)	4.1 (4.0–4.2)
1920		2.5 (2.1–3.0)	2.9 (2.6–3.2)	3.1 (2.9–3.3)	3.1 (3.0–3.2)	3.0 (2.9–3.1)
1925	2.5 (1.8–3.3)	2.8 (2.3–3.3)	2.7 (2.5–3.0)	2.7 (2.6–2.9)	2.6 (2.5–2.7)	2.5 (2.5–2.6)
1930	2.0 (1.5–2.6)	2.8 (2.4–3.3)	2.5 (2.3–2.8)	2.4 (2.2–2.5)	2.1 (2.1–2.2)	2.1 (2.1–2.2)
1935	2.3 (1.7–3.1)	2.4 (2.1–2.8)	2.1 (2.0–2.3)	1.8 (1.7–1.9)	1.8 (1.8–1.9)	1.8 (1.8–1.9)
1940	2.1 (1.5–2.9)	1.8 (1.5–2.1)	1.7 (1.6–1.8)	1.6 (1.6–1.7)	1.6 (1.6–1.7)	1.6 (1.6–1.7)
1945	1.7 (1.2–2.2)	1.6 (1.4–1.9)	1.5 (1.4–1.6)	1.5 (1.5–1.6)	1.5 (1.4–1.5)	1.5 (1.5–1.5)
1950	1.5 (1.2–2.0)	1.3 (1.2–1.6)	1.4 (1.3–1.5)	1.5 (1.4–1.6)	1.4 (1.4–1.5)	
1955	1.7 (1.3–2.3)	1.4 (1.3–1.7)	1.4 (1.3–1.5)	1.3 (1.3–1.4)		
1960	1.2 (0.9–1.6)	1.2 (1.0–1.4)	1.1 (1.0–1.1)			
1965	1.2 (0.9–1.5)	1.2 (1.0–1.4)				
1970	1.1 (0.8–1.4)					
Blacks						
1865						
1870						
1875						
1880						
1885						
1890						
1895						
1900						5.2 (4.5–6.0)
1905					4.2 (3.6–5.0)	6.1 (5.3–7.0)
1910				3.4 (2.8–4.3)	5.5 (4.7–6.4)	6.5 (5.8–7.2)
1915			3.1 (2.3–4.2)	4.2 (3.5–5.1)	5.5 (4.8–6.2)	6.1 (5.6–6.7)
1920		2.2 (1.4–3.3)	3.8 (2.9–4.9)	4.5 (3.9–5.2)	4.9 (4.4–5.4)	4.7 (4.4–5.0)
1925		2.5 (1.7–3.7)	4.0 (3.2–5.0)	4.4 (3.9–5.0)	3.7 (3.5–4.1)	4.0 (3.8–4.3)
1930		3.8 (2.7–5.5)	3.1 (2.6–3.8)	3.1 (2.7–3.4)	3.4 (3.1–3.6)	3.2 (3.0–3.4)
1935		3.0 (2.1–4.2)	2.9 (2.4–3.5)	3.0 (2.7–3.3)	3.0 (2.8–3.2)	3.0 (2.8–3.2)
1940		3.1 (2.1–4.4)	2.4 (2.0–2.9)	2.8 (2.5–3.1)	2.8 (2.6–3.0)	2.8 (2.6–2.9)
1945		2.4 (1.7–3.3)	2.6 (2.2–3.1)	2.5 (2.3–2.8)	2.7 (2.5–2.9)	2.6 (2.4–2.7)
1950		2.6 (1.9–3.6)	2.4 (2.1–2.8)	2.4 (2.2–2.7)	2.3 (2.1–2.4)	
1955		2.0 (1.5–2.7)	2.0 (1.7–2.3)	1.9 (1.7–2.1)		
1960		2.1 (1.6–2.7)	1.5 (1.3–1.7)			
1965		1.3 (0.9–1.9)				
1970						

[1]Rate ratios for ages 25–59 years in blacks were excluded because of few deaths. Nonwhite rates used as surrogates to estimate the ratios in blacks for deaths 1950–69.

panel) and for blacks (*lower panel*) ages 35–54. Among whites, rates appeared to be converging rapidly for adenocarcinoma, small cell carcinoma, and large cell carcinoma, but less so for squamous cell carcinoma. Using the most stable age-specific rates, ages 50–54 whites, the male-to-female histology-specific rate ratios for cohorts born around 1925 to cohorts born around 1945 decreased from 1.7 (95% CI = 1.5–1.9) to 0.9 (95% CI = 0.8–1.0) for adenocarcinoma, from 2.0 (95% CI = 1.7–2.3) to 1.2 (95% CI = 1.0–1.4) for small cell carcinoma, and from 3.8 (95% CI = 3.3–4.4) to 2.1 (95% CI = 1.8–2.5) for squamous cell carcinoma. For large cell carcinoma, the male-to-female rate ratio for ages 50–54 decreased from 1.8 (95% CI = 1.5–2.1) to 1.2 (95% CI = 0.9–1.5) for cohorts born around 1930 and 1945, respectively. It is noteworthy that adenocarcinoma rates were slightly higher in women than in men born after 1940. The histology-specific lung cancer incidence patterns for black men and women (Fig. 2, *lower panel*) were based on sparse data; however, they are generally similar to the patterns observed for white men and women, with less pronounced convergences of rates between

genders. The histologic-specific trends described here were unlikely to be greatly influenced by coding-induced biases because the proportion of other specific and non-specific histologic types of carcinoma of the lung changed very little over-time, from 17% for cases diagnosed between 1975–79 to 20% between 1995–99.

Figure 3 shows trends in the prevalence of current smoking among white and black men and women for two selected ages, age 24 and 40 years, by birth cohort.[27] In both blacks and whites, smoking prevalence appeared to be higher at age 40 years than at age 24 years for women born before 1930 whereas they are fairly similar for men born before 1915. For cohorts born thereafter, however, prevalence of smoking at age 40 years appeared to be lower than the prevalence at age 24 years, demonstrating increased smoking cessation, which is more pronounced in men than in women and in whites than in blacks. In addition, the prevalence of smoking at each age has converged between men and women in successively younger birth cohorts, but more strikingly in whites than in blacks.

TABLE I – MALE TO FEMALE LUNG CANCER MORTALITY RATE RATIOS (95% CI)[1] (CONTINUED)

			Age			
55–59	60–64	65–69	70–74	75–79	80–84	85+
						2.4 (2.2–2.7)
					2.4 (2.2–2.6)	2.9 (2.6–3.1)
				3.1 (3.0–3.3)	3.3 (3.1–3.5)	3.2 (3.0–3.4)
			4.2 (4.1–4.4)	4.5 (4.3–4.7)	4.4 (4.2–4.6)	3.5 (3.3–3.7)
		6.1 (5.9–6.4)	6.2 (6.0–6.5)	6.1 (5.9–6.4)	5.2 (5.0–5.4)	4.2 (4.0–4.4)
	7.0 (6.7–7.3)	8.3 (8.0–8.6)	8.0 (7.7–8.3)	7.1 (6.8–7.3)	5.9 (5.7–6.1)	4.4 (4.3–4.6)
7.7 (7.3–8.0)	9.1 (8.8–9.5)	9.3 (9.0–9.6)	8.1 (7.8–8.3)	6.9 (6.7–7.1)	5.7 (5.6–5.9)	4.4 (4.3–4.5)
8.6 (8.2–9.0)	9.0 (8.7–9.3)	8.1 (7.9–8.3)	7.0 (6.9–7.2)	5.9 (5.8–6.1)	4.9 (4.8–5.0)	4.0 (3.9–4.1)
7.4 (7.2–7.7)	7.2 (7.0–7.4)	6.2 (6.1–6.3)	5.4 (5.3–5.5)	4.6 (4.5–4.7)	3.9 (3.8–4.0)	3.4 (3.3–3.4)
5.3 (5.2–5.5)	4.9 (4.8–5.0)	4.3 (4.3–4.4)	3.7 (3.7–3.8)	3.3 (3.2–3.3)	2.9 (2.9–2.9)	2.7 (2.6–2.7)
3.7 (3.6–3.8)	3.5 (3.4–3.6)	3.1 (3.0–3.1)	2.8 (2.7–2.8)	2.4 (2.4–2.5)	2.2 (2.2–2.3)	
2.9 (2.8–2.9)	2.7 (2.7–2.7)	2.5 (2.4–2.5)	2.2 (2.2–2.2)	2.0 (2.0–2.0)		
2.4 (2.4–2.5)	2.3 (2.3–2.3)	2.1 (2.1–2.2)	1.9 (1.9–2.0)			
2.1 (2.1–2.1)	2.0 (2.0–2.0)	1.9 (1.8–1.9)				
1.8 (1.8–1.8)	1.7 (1.7–1.7)					
1.6 (1.6–1.7)						
						2.4 (1.4–4.0)
					3.6 (2.3–5.4)	4.3 (2.8–6.7)
				3.6 (2.7–4.7)	3.9 (2.8–5.3)	3.5 (2.6–4.8)
			3.6 (2.9–4.4)	3.9 (3.2–4.8)	4.6 (3.7–5.8)	3.9 (3.1–4.8)
		4.7 (4.0–5.5)	4.7 (4.0–5.5)	5.9 (5.0–7.1)	4.2 (3.5–5.0)	3.9 (3.3–4.7)
	7.4 (6.2–8.9)	5.9 (5.2–6.7)	8.0 (7.0–9.2)	6.5 (5.7–7.4)	5.8 (5.0–6.7)	4.3 (3.7–4.9)
5.7 (4.9–6.7)	6.8 (6.0–7.7)	8.2 (7.3–9.2)	7.4 (6.7–8.2)	6.6 (5.9–7.3)	5.9 (5.2–6.6)	3.9 (3.5–4.3)
6.9 (6.1–7.9)	7.2 (6.5–8.0)	7.0 (6.4 (7.6))	6.3 (5.8–6.8)	5.8 (5.4–6.3)	4.9 (4.5–5.4)	4.1 (3.7–4.4)
7.2 (6.4–8.0)	7.5 (6.8–8.2)	7.2 (6.6–7.7)	6.3 (5.9–6.7)	5.6 (5.2–5.9)	4.7 (4.4–5.1)	3.5 (3.3–3.8)
6.3 (5.8–6.9)	6.8 (6.3–7.3)	6.3 (5.9–6.6)	5.6 (5.3–5.9)	4.9 (4.7–5.2)	4.2 (4.0–4.5)	3.1 (2.9–3.3)
5.7 (5.4–6.2)	5.5 (5.2–5.8)	5.0 (4.8–5.2)	4.4 (4.2–4.6)	3.6 (3.5–3.8)	3.2 (3.1–3.4)	
4.9 (4.7–5.2)	4.2 (4.0–4.4)	4.0 (3.9–4.2)	3.4 (3.2–3.5)	2.9 (2.8–3.0)		
3.5 (3.3–3.7)	3.4 (3.2–3.5)	3.1 (3.0–3.3)	2.6 (2.5–2.7)			
3.1 (3.0–3.3)	3.0 (2.9–3.1)	2.5 (2.5–2.6)				
2.9 (2.8–3.1)	2.7 (2.6–2.9)					
2.7 (2.6–2.8)						

DISCUSSION

We found that lung cancer mortality and incidence rates are converging between young white men and women in the U.S. Further, incidence rates are converging for adenocarcinoma, small cell carcinoma, and large cell carcinoma, and to a lesser degree for squamous cell carcinoma. Although steady reductions in the male-to-female age-specific mortality and incidence rate ratios with successive birth cohorts were also observed among blacks, the convergence to unity is less striking. Similar converging patterns were noted in the U.K.[29] and Australia.[30]

The striking convergence of lung cancer rates between young white men and women but not between black men and women reflect the similarity and differences in smoking patterns among white and black men and women. After the Surgeon General's report in 1964 on the association of cigarette smoking and health outcomes and subsequent anti-smoking campaigns, overall smoking prevalence in adults declined, though more rapidly among men than among women. In general, increasing cessation rates and declining initiation rates were more pronounced in men than in women and in whites than in blacks.[27,31,32] Rates of initiation among men and women, especially in whites, have become increasingly similar in the recent birth cohorts,[33] as is evidenced by the prevalence of current smoking at age 24 years (Fig. 3). Differences in prevalence of current smoking between men and women at age 40 years were smaller in whites than in blacks, presumably due to higher rates of quitting among white men compared to black men. Differences in the prevalence of current smoking at age 40 years are especially important because lung cancer risk is directly related to duration of smoking.[34] These differences and similarities in ethnic group- and gender-specific smoking patterns appear to explain the higher male-to-female lung cancer mortality rate ratios in blacks than in whites for people born after 1915 and the more strikingly converging cancer mortality and incidence rates observed in whites than in blacks. In other words, although rates for males remain above those for females during the entire monitoring period, we have observed similar lung cancer rates for white males and females in cohorts with similar smoking prevalence, *i.e.*, cohorts born after 1960, and the trend toward
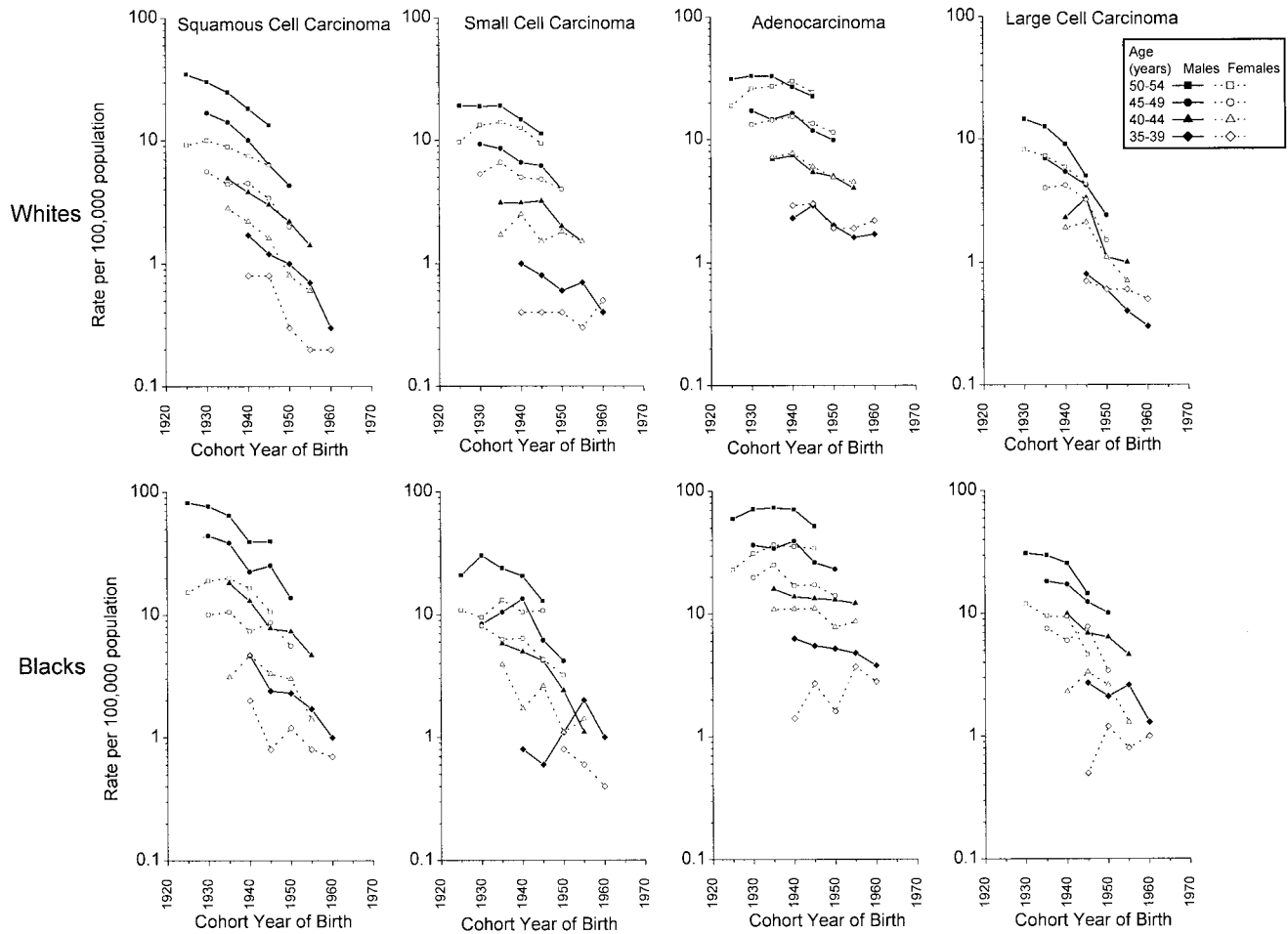
Figure 2 – Age-specific lung cancer incidence patterns among white and black males and females by birth cohort (1925–60) for 4 major histologic types, SEER Program.

similar rates for black males and females consistent with their trends toward similar smoking prevalence.

Many analytical studies have indicated that for equal level of cigarette smoking exposures, women have higher risks of lung cancer compared to men.[6–13] For example, Risch et al.[8] reported that the risk of developing lung cancer among persons with a history of 40 pack-years smoking relative to lifelong nonsmokers was 27.9 (95% CI = 14.9–52.0) among women and 9.6 (95% CI = 5.6–16.3) among men. Our finding that the lung death rate is about equal between young men and women born after 1960s, however, is consistent with recent findings from the U.S.[14] and European countries[15–17] that do not support a higher susceptibility of women to tobacco smoke. The largest cohort study in the U.S. (Cancer Prevention Study II) showed that women have similar or lower death rates from lung cancer than men within comparable strata of age and smoking.[14]

Reasons for the weaker convergence in the rates of squamous cell carcinoma of the lung between men and women are unknown. Stellman et al.,[35] however, reported that the relative risk of squamous cell carcinoma among lifetime filter cigarettes smokers to lifetime non-filter cigarettes smokers was reduced significantly among women (by 60%) and non-significantly among men (by 30%). Whether this gender difference may in part play a role for the weaker convergence in squamous cell carcinoma is unclear. Nonetheless, the reduction in risk of squamous cell carcinoma associated with filter cigarettes, in addition to declining smoking

prevalence, may have contributed to the rapid decline of cancer of this histologic type in both men and women. Cohorts born after 1940 predominantly have smoked filter-tipped cigarettes,[36] with lower tar yield, as the market share of filter-tipped cigarettes in the U.S. increased from <1% in 1950 to 51% in 1960 and 98% in 1998.[37] It is worth mentioning, however, that recent findings in the U.S. concluded that "low yield" cigarettes do not reduce the overall risk of lung cancer.[38,39]

The slightly higher adenocarcinoma incidence rate for women than men among whites born after 1940 is remarkable in light of the generally higher rates in men for lung cancer. Prevalence of smoking for cohorts born around 1940 appears to be lower in women than in men and does not explain the excess risk among women. A difference in the proportion of men and women who smoke filter-tipped cigarettes, which may cause primarily adenocarcinomas of the lung, is unlikely because cohorts born after 1940 smoked almost exclusively filter-tipped cigarettes.[36] In view of the fact that adenocarcinoma is the most frequent type of lung cancer in non-smokers, it may be that women have a higher proportion of adenocarcinoma cases in non-smokers than men, although Zang and Wynder[7] reported an apparently similar proportion of non-smoking lung cancer cases for age under 55 years.

There are certain limitations in our study. The histologic-specific trends for the most recent birth cohorts were based on few counts and the data should be interpreted with caution. Further-

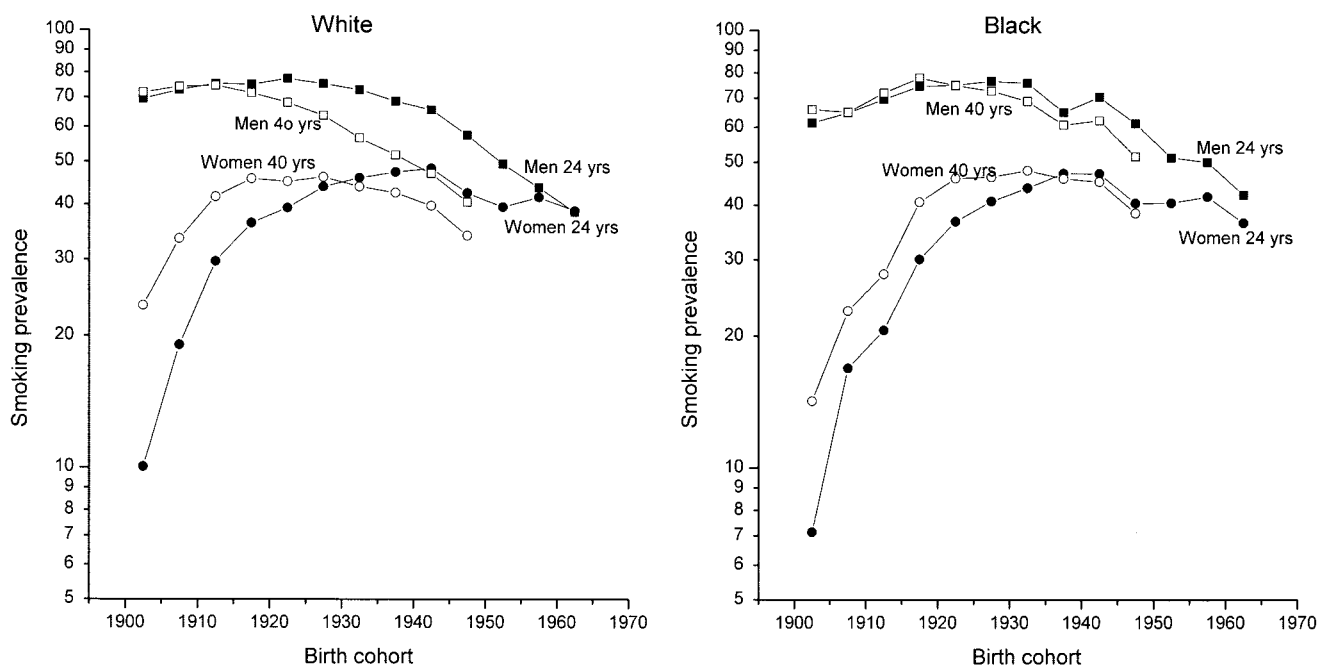## Smoking prevalence patterns for selected age by birth cohort

FIGURE 3 – Current prevalence of cigarette smoking for ages 24 and 40 years by ethnic group and gender, 1965–90.[27]

more, the formation of birth cohorts was based on 5-year age and time intervals, *i.e.*, 10-year birth-cohort interval, with some overlap between 2 consecutive birth cohorts. Ten-year birth cohort interval, however, is the most optimal and frequently-used approach for graphical display of data.

Despite these limitations, the convergence of lung cancer death rates among men and women born after 1960s supports the idea that males and females maybe equally susceptible to develop lung cancer from a given amount of cigarette smoking, rather than the hypothesis that women are more susceptible.

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